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Methods of Trench Excavation

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METHODS OF TRENCH EXCAVATION

BY

BEN J. WILSON

THESIS

FOR THE

DEGREE OF BACHELOR OF SCIENCE

IN

CIVIL ENGINEERING

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May 24, 1912

This is to certify that the thesis of BEN J. WILSON entitled METHODS OF TRENCH EXCAVATION was prepared under my personal supervision; and I recommend that it be approved as meeting this part of the requirements for the degree of Bachelor of Science in Civil Engineering.

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METHODS OF TRENCH EXCAVATION

INTRODUCTION

The selection of the method best suited, and hence the efficiency of the work upon which any trench excavation depends, rests entirely upon the judgment of the person in charge. For this reason the importance of a thorough study of the various methods available cannot be too strongly emphasized.

The object of this thesis is to discuss the different methods of trench excavation now in use, to compare these methods, and to consider as far as possible the relative costs. Reliable cost data for hand excavation are very difficult to obtain, as labor costs, etc., vary so greatly with different localities and conditions.

TRENCH EXCAVATION BY HAND LABOR

It will be found more convenient to discuss the methods of excavating trenches by hand if the subject be divided into two parts: shallow trenches and deep trenches. Trenches up to six feet in depth will be termed shallow, and all over this depth, deep trenches. The former will first be discussed.

In trenching, as in most other kinds of work, the arrangement of men is of vital importance. The success obtained in trench excavation depends a great deal upon this question. There are two general methods in use. In the first method several men are set to work at equal intervals along the trench, loosening the earth with picks. The first man starts digging at the head, or one end of the trench, and excavates from one to three spade blades in depth; following him another man digs the same depth, and so on until the required depth is dug. The depth that each man digs depends upon the depth of the trench, and the number of men employed. This method is generally used. It gives a clean trench, and avoids the danger of having the sides broken by the laborers after the trench is dug. This method is very effective in loam or clay.

As fast as any portion of the trench is completed, the pipe, or tile, can be laid, and the back filling started. The laying of the pipe will be a kind of a pacemaker for the

excavating laborers, and no loafing can be done without interfering with the work of the men behind them.

In the second method each man is assigned a section of the trench from eight to fifteen feet in length, and is required to dig to the specified depth. Several men can be placed at equal intervals, and are responsible for the trench in the section assigned. The foreman has a close check upon the amount of dirt each man digs, which is about the only advantage of this method. This arrangement of men increases the danger of caving in the sides of the trench. It is also impossible to follow the excavating laborers closely with pipe laying, which is an evident disadvantage if the time is limited.

In the second method, trenches of a width greater than 18 or 24 inches will be considered. For increasing width, a different arrangement of men is found expedient. Here it is found to be more efficient if two men work on the same level. By this is meant that while in narrow trenches, one man dug from one to three spade depths the entire width of the trench; now two men may be placed side by side, digging to the same depth. By this arrangement of men progress is more rapid, in that the men can be paired off to good advantage, and more men be employed.

It is difficult to obtain costs on varying widths, but it is undoubtedly true that the cost increases somewhat less rapidly than the width of the trench. The conditions under which costs are determined are so different in the different

localities that no definite figures can be fixed.

Deep trenches require rehandling of the earth. Trenches over six feet in depth require scaffolding. The labor unions now specify that platforms shall not be placed at intervals exceeding four feet. The platforms should be placed at distances along the trench not exceeding fifteen feet, and be at least five feet long. Trenches requiring platforms usually have their sides braced, and erection is easily accomplished. For trenches in which more than one platform is required, it is found to be best to stagger them for easy handling of the material.

After the depth of the trench exceeds six feet, it will no longer be advisable to arrange the men as described under shallow trenches. Platforms should be erected, and one man placed on each platform, with one man working on each side of the platform in the bottom of the trench. The platform men use the same shovel as the surface men.

In the excavation of many trenches treacherous soils are encountered. When this condition occurs, the cost and time required increase rapidly. Soils of this nature require bracing. Sheeting a trench by hand is best done by using vertical sheeting of two inch thickness, 8 inches to 10 inches in width, and 12 or 14 feet long. Larger sizes are inconveniently heavy and hard to handle. The upper end is trimmed to 6 inch width to admit of using a cast steel or wrought iron cap to protect the end of the sheeting when being driven.

The lower end is sharpened like a chisel with the bevel towards the center of the trench.

Mauls for hand driving are made of live oak, hickory, or iron wood, with hickory handles. The striking face of the maul is 5 inches in diameter, and at the eye for the handle the diameter is 6 inches or 7 inches. Wrought iron rings, 3/8" by 1 1/2" are driven on the ends and fastened by oak wedges or 1/4" boat spikes.

In sand trenches, sheeting should always be driven with the aid of a water jet to assist the maulers. The economy in labor and lumber is so great as to make it imperative. The water pressure should be about 100 pounds per square inch at the nozzle. The point of the jet should be 3/4" diameter.

Pumping ground water from sand trenches will prove to be an expensive operation if ample preparations of thoroughly efficient apparatus are not made and kept ready for use. In wet trench work there is probably no way in which the expense can be increased so fast as trying to excavate with an inadequate or insufficient disposal of trench water.

Hand pumping is usually done by means of diaphragm pumps. In order to pump rapidly, such a pump usually requires three men to man it effectively. There are now on the market combinations of the diaphragm pump fitted to a small gasoline engine. These arrangements are so light, cheap, and economical in operation that there is little excuse for continuing

the practice of pumping by hand, except on small jobs.

Where possible to do so, the most satisfactory method of handling water is to pump it before it enters the trench. In sandy soil this is done by using the well-point pumping system.

No accurate data can be obtained concerning the cost of trench excavation by hand. There are a few tables of cost in Gillett's hand book, but they are of little value except for rough estimates, as no definite conclusion can be drawn under varying conditions.

The workmen, to do good efficient work, must have good sharp shovels, and of the proper shape. The shovels used for depths up to four feet should be of different shape from those used from the depth of four to six feet. The best types to use in loam, clay, and soils resembling these, to depths of four feet are: the tile spade, the taper square pointed, and the socket square pointed spade. All of these named are short handled, and shaped in such a way that a comparatively small amount of energy is required by the user in sinking it into the earth. The handles are of such a length that the earth can be easily thrown back from the edge of the trench.

For depths greater than four feet, in clay or loam, it is found to be more beneficial to use the following types of shovels: the square pointed, the crum, and the long handled pointed shovel. The shovels are all long handled, giving greater leverage and greater reach. The bladesare dished,

making it easy to secure a full blade each lift. By having long handles, the dirt is easily kept away from the sides of the trench.

In sandy soils and very loose material, the short handled railroad tie,and crum shovels are found to serve to the best advantage. The shapes of the blades are such as will make it possible to secure almost as much earth on the blade as is secured in loam or clay.

The lower lifts of earth are the most expensive to excavate, and care, coupled with good judgment, should be used in selecting the most efficient shovel.

On work in which the laborers are working under conditions in which it is impossible for them to throw the earth back far enough to keep it from rolling back into the trench, a surface man is needed. It is the duty of this surface man to keep the dirt back at least one and one-half feet from the edge of the trench. The railroad tamping shovel is the best to be used as the earth is loose and is not moved a great distance.

POTTER MACHINE

The Potter Trench machine is nothing more than a means of conveyance for the earth shoveled by laborers, and it cannot, therefore, really be classed as a trench machine. It is of great aid, in trenches dug by laborers, where the material must be conveyed some distance.

Figure 1 (on the following page) shows the general construction. The steel trestle is strongly bolted together, and is composed of 17 sections, each 16 feet long, making the entire length 272 feet. The machine is mounted on wheels which makes it easy to pull forward as the work progresses. The span of their standard machine is 10 feet 6 inches, and the height of the trestle is about 7 feet.

The important feature of the machine is the conveying car. It is simply constructed, and hoists and carries two buckets at a time. The main shaft is locked in any position by means of ratchet and pawl; the hoist is arranged with a pull wheel and drum.

At one end of the trestle is located the hoisting engine that furnishes the power to run the bucket car and buckets. It is claimed that the time required to hoist two buckets and run the car back and forth the length of the trestle is one minute.

The force required for operating this machine is comparatively small. One man can operate the hoisting engine, and two men are required on the bucket car. The buckets are

made of steel, and vary from 1/3 to 1 cubic yard in capacity.

Figure 1.

TRENCH EXCAVATION BY POWER MACHINES

On large jobs, excavation by hand is tedious and costly. The great amount of trench excavation that has been done in the last fifty years has lead men to produce power machines for trenching. It was soon learned, after the introduction of trench machines, that both time and cost of excavating were greatly reduced, and with this object in view the machines of today are ones of great efficiency.

The advantages claimed by manufacturers of machines are that the contractor's theoretical estimate of cost of excavation on sewer work, or the time in which work can be done, is rarely if ever borne out in practice, due often to the fact that the character of excavation proves other than expected; also difficulty in getting the right kind of help, or enough of it, higher price for labor, and other unlooked for contingencies as labor disturbances, etc. Skilled labor in large cities is, as a rule, unionized and high priced. In smaller places it is difficult to obtain help, and if it can be had, it is not generally of a desirable quality. In almost any part of the country men will do almost any kind of work other than dig trenches. The machine meets all these conditions, placing the contractor in a perfectly independent position, and practically insuring him against loss from the troubles mentioned, and enabling him to figure on work without reference to the labor market.

The manufacturers of the machines also claim that the machines will work in any kind of soil that can be plowed

or picked, no matter how hard or sticky. They will not work in quicksand or where there are many boulders, large roots, or pipes.

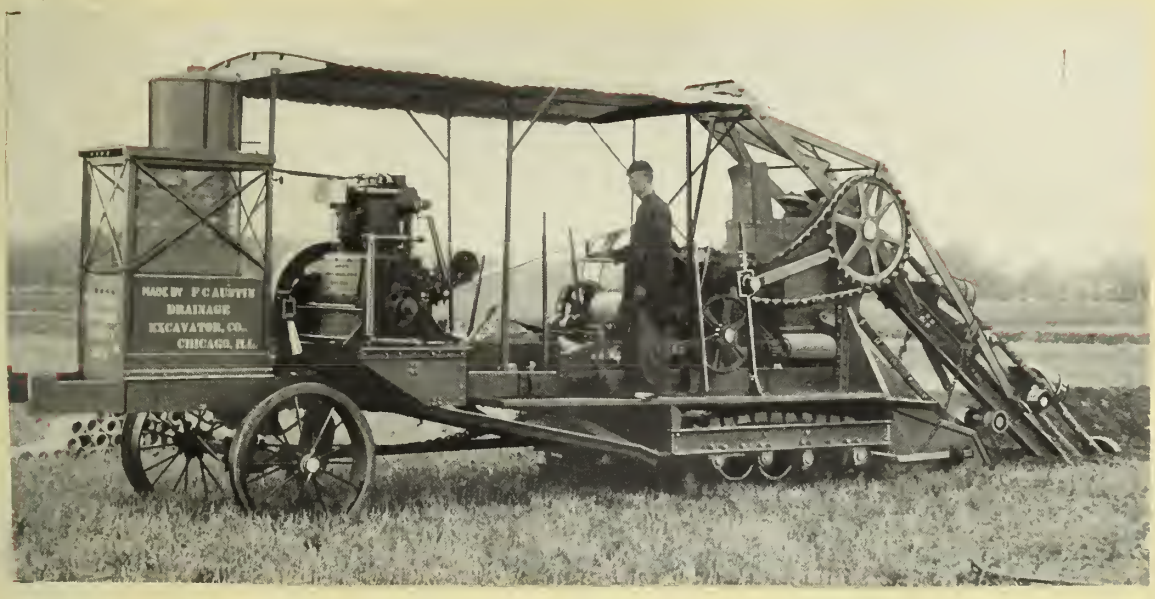
The foremost machines upon the market at present are the Austin, Parson, Potter, Chicago, Buckeye, and American. These machines are divided into chain and wheel excavators. Under the former are the Austin, Parson, and Chicago; and under the latter are the Buckeye and American.

Chain and wheel excavators resemble each other in many principles. The essential difference in the chain and wheel excavators is the path traveled by the buckets. In the chain excavator the buckets are connected to an endless chain, whose path is roughly the perimeter of a rectangle. In the wheel type, the buckets are securely riveted to a heavy piece of steel whose path is the circumference of a circle. The accompanying figures show very clearly the distinguishing features.

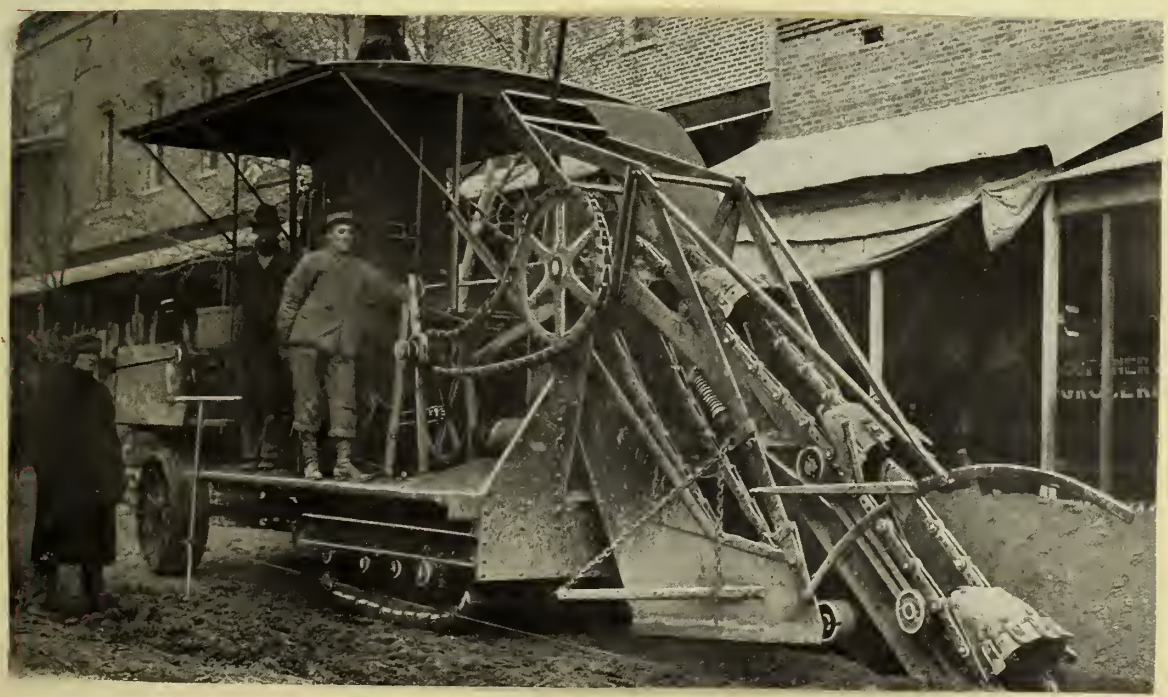
The F. C. Austin Drainage Excavator Co., make ten sizes of trench excavators. These machines are made practically of steel. The frame is made of structural steel; the sprocket wheels, gears, and pinions of cast steel.

The entire machine is mounted on a roller platform traction, as shown in Sketch No. 1, (on the following page). Each of these tractors has 10 square feet of ground surface, giving them a pulling power of approximately 6 to 1 over wheeled machines; and owing to this wide surface, the machine

will not mire, but will travel over ground so soft that a team could not be driven across it.



Sketch 1.



Sketch 2.

Sketch No. 2 (on the preceding page) shows the self-cleaning buckets with tool-steel cutting edges, which are a distinctive feature of this type of machine. Another feature about this machine is the quality chain that carries the buckets. Each link is attached to the other by a steel pin, having an outside collar made of manganese, the hardest and toughest castings known.

A feature of the machine is that it will cut almost square corners. The feat is not accomplished by other machines. In making these turns, the spread of the machine is not diminished. Sketch No. 3 (on the following page) shows the No.00 machine excavating near Zion City, Illinois. Note the short turns.

All sizes of trenching machines are equipped with caterpillar traction only, with the exception of sizes No. 0000 and No. 1, the No. 0000 being equipped with steel wheels only, and the No. 1 with either steel wheels or caterpillar traction. The digging buckets are of the scoop type, strongly reinforced with chilled steel lips, which are again protected by manganese steel spuds or reamers attached for the purpose of taking care of hard or stony ground.

Road speeds and digging speeds are shown in the following schedule, (on page 15).

Sketch 3.

Size No.	Horse Power Steam	Horse Power Gasoline	Maximum Depth	Width of Cuts	Maximum Digging Speed per Minute
0000		12	4'-6"	12"	15 feet
000		18	6'-0"	12"-15"-18"	10 "
00	12	18	8'-0"	15"-18"-24"	8 "
Special 00	18	24	9'-6"	15"-18"-24"	9 "
Ex.Spec. 00		36	9'-6"	15"-18"-24"	9 "
0	18	36	10'-0"	18"-24"-30"	10 "
1	25		12'-0"	18"-24"-30"-36"	6 "
1		50	12'-0"	18"-24"-30"-36"	6 "
1	25		12'-0"	18"-24"-30"-36"	6 "
1		50	12'-0"	18"-24"-30"-36"	6 "

Size No.	Traction Speed per Hour	Delivering Dirt One or Both Sides	Width of Machine on Car	Height of Machine	Approximate Gross Weight
0000	1 1/2 miles	One Side	9'-0"	8'-6"	12,000
000	1 1/2 "	" "	8'-0"	10'-0"	18,000
00	1 1/2 "	Either "	9'-0"	11'-0"	22,000
Special 00	1 1/2 "	" "	9'-0"	11'-0"	22,600
Ex. Spec. 00	1 1/2 "	" "	9'-0"	11'-0"	23,200
0	1 1/2 "	" "	10'-0"	12'-0"	32,000
1	1 1/4 "	" "	10'-0"	14'-0"	48,000
1	1 1/4 "	" "	10'-0"	14'-0"	47,000
1	1 1/4 "	" "	10'-0"	14'-0"	50,000
1	1 1/4 "	" "	10'-0"	14'-0"	49,000

The cost of operation will run from $7.50 to $12.50 per day of 10 hours, depending on the size of the machine. An Austin trench machine of the Municipal Engineering Co., was used at Clearing, Illinois, in a clay soil for a 4 ft. width of trench. The quantities of excavation given below are net quantities corresponding to the depth on this particular job.

Size of trench, 8 ft. 5 in. deep, 4 ft. wide, 2974 ft. long

Volume of excavation ..... 3745 cu.yds.

Time of digging .....72 hrs. 30 min.

Delays chargeable to machine ..... 39 hrs. 0 min.

Delays chargeable to contractor ..... 42 hrs. 40 min.

Total time of work .....154 hrs. 10 min.

Time of excavation per day ..... 9 hrs. 0 min.

Rate of digging time ..... 372 lin. ft. or 468 cu.yds

Rate of total time ..... 173 lin. ft. or 220 cu.yds

Maximum day's work, including 1 hr. 20 min. delay ... . 455 lin. ft. or 549 cu.yds.

Expense

1 Operator	$5.00	per day
1 Engineer and Fireman	3.50	" "
1 Team for coal and water	5.50	
4 Laborers for runways and placing deadman logs, each at $2.50	10.00	
Rental, together with charge of 10¢ per cu. yd.	10.00	

About half a ton of coal per day was burned.
This daily expense was equal to $0.274 per cu. yd. of effective excavation of the trench.

CHICAGO MACHINE

Another chain type machine which is used very extensively in trench excavation is the Chicago. This machine is manufactured by the Municipal Engineering and Contracting Co., of Chicago. There are nine types of this machine. The following schedule gives in detail a description of the different types.

Size No.	Kind of Power	Horse Power	Maximum Depth	Approximate Widths	Maximum Speed of Digging per Hour
00	Gasoline	18	8'	15, 18 and 24	8'
00	Steam	12	8'	15, 18 and 24	8'
0	Gasoline	36	10'	19 and 26	10'
1	Steam	20 9x11	12'	(19, 24, 27, (32 and 36	4'
1	Gasoline	45	12'	(19, 24, 27, (32 and 36	4'
1 1/2	Steam	40 10x10	14'	(19, 24, 27, (32 and 36	4'
1 3/4	"	40 10x10	15'	27, 32, and 36	2 1/2'
2	"	50 DoubleEng 8x10	15'	(27, 32, 36, (and 48	3'
3	"	70 12x12	25'	(27, 32, 36, (48 and 60	3'

Size No.	Miles Traction per Hour	Delivers Dirt on One Side or Either Side	Width on Car	Height Over All
00	1 1/2	One Side	9'	11'
00	1 1/2	One Side	9'	11'
0	1 1/2	Either Side	10'	12'
1	1 1/4	Either Side	10'	14'
1	1 1/4	Either Side	10'	14'
1 1/2	1 1/2	Either Side	10'	14'
1 3/4	1 1/2	Either Side	10'	15'
2	1 1/2	Either Side	10'	15'
3	1 1/2	Either Side	10'	15'

These machines are very rigidly built, as is shown in the following cuts, (Fig. / and Fig. 2). The machines are not complicated, but comparatively simple in construction; yet they are heavy as shown by the weights in the above schedule.

Most of the machines are equipped with the rolling platform traction, which is very flexible and will pass over any ordinary obstructions.

A feature about these machines, which is not found in any of the other makes, is that they have various changes of speed, and are changed instantaneously by the operator. Another convenient feature of these machines is the fact that they can be operated in alleys from widths of 12 ft. up.

Figure 1

Figure 2

All of the machines, excepting the No. 2, are self-contained; i.e., the power is mounted on the machine itself. The No. 2 is operated by a special traction engine, which pulls the outfit.

On all sizes, excepting the No. 2, the wheels of the machine are in advance of the excavation, thereby avoiding pressures on banks.

Sketch No. 2 shows the No. 0 machine ready for traveling. This sketch shows clearly the mechanism of the machine, and the simplicity with which the bucket arm is elevated.

On ordinary digging the No. 1 and No. 1 1/2 are self propelling when at work. The larger sizes work to better advantage when anchored to a "dead man". This is not used, however, except when the machines are digging.

The machines are arranged with several speeds, so that they can be operated more slowly or more rapidly as conditions permit. The speed at which the No. 1 and No. 1 1/2 machines dig, while governed entirely by the conditions of the soil, is one or two lineal feet per minute. All sizes are geared to run at a speed upwards of two feet per minute, except in deep cuts. The earth can be thrown to either side.

The following table compares the cost of excavating by the No. 3 and No. 1 machines to those of hand excavation. It is assumed that the men dig and throw back ten yards per day; wages $2 per day of ten hours. The bottom man raises

to a bench, and scaffolds are four feet apart to the top. On the top is a bank-man to throw the dirt back.

Depth of trenches	8' - 12' - 16' - 20'			
Number of lifts	1 1/2	2 1/2	3 1/2	4 1/2
Number of men	2	3	4	5
Daily Average No. cu. yds. per man ...	5.7	4.4	3.3	2.5
Cost per cubic yard	35¢	48¢	60¢	80¢
Cost per linear foot of trench 27" wide	24¢	45¢	80¢	$1.33
100 men would excavate per day, cu. yds.	570	440	330	250
100 men would excavate per day, linear feet	805	440	247	150

It has been found that with the larger sizes of the machines, as the No. 1 and No. 3, in a trench of 27" wide for a 10 hour day, that the cost for trenches from 8 to 20 feet in depth varies per lineal foot as follows:

No. 3 Machine	Yards	Width	Depth	Cost	Depth	Cost
Output	300	27"	8'	11¢	20'	50¢
"	400	27"	8'	8.5¢	20'	43¢
"	500	27"	8'	7¢	20'	38¢
No. 1 machine						
Output	200 to 500	24"	5'	Cost varies from 4 to 7 cents per lineal foot.		

Sketch No. 3 shows one of the machines working in a narrow alley. An alley is an awkward place for a machine to work, but it can be seen from the cut that the machine has

successfully kept the earth back from the sides of the trench, and that it has also made a clean trench.

PARSONS MACHINE

The trench machine manufactured by the G. W. Parsons Co., of Newton, Iowa, is somewhat similar to those described. The frame is constructed of structural steel shapes, the entire framework being set on heavy steel channels and securely fastened. Crucible steel castings are used in all parts liable to be subjected to strains, jolts, or rough usage. The machine, over all, is but ten feet in width. The carrier is constructed entirely of steel and is extensible, so that excavated material can be placed at varying distances from the trench. The machine is self-propelling, moving of its own power when digging, at speed desired, and when moving from place to place at a rate of two to three miles per hour.

The machine is designed in such a way that with adjustment it can dig a trench from widths of 28" to 60". In order to change the width of the trench, it is necessary to loosen and set two small set screws. Figure No. 1 shows the position of the buckets in the trench ready for excavating. In excavating a wider trench, the same set of buckets do all the work. The buckets and the framework upon which they travel move backward and forward across the face of the trench upon a square shaft; the sprocket wheels driven by this shaft, upon which the buckets travel, are mounted on roller bearings, and this allows the oscillating movement on the shaft.

The machine is rated at a capacity of 3/4 of one cubic yard per minute. It is claimed that this machine will excavate in a trench 28" x 6'0", 869 lineal feet of trench for each ten hours of operation.

Figure 1.

BUCKEYE MACHINE

The Buckeye Trench Excavator is perhaps the best known of the two named wheel type. This machine is manufactured by the Buckeye Traction Ditcher Co., of Findlay, Ohio. This company makes 36 types of machines. Sizes from 1 to 13 are known as drainage machines, while the remaining 23 are called contractors' machines. The machines are able to dig trenches from 11 1/2 in. x 4 1/2 ft. to 54 in. x 12 ft.

The Buckeye Trench Excavator is a traction engine, on the rear end of which is mounted an excavating wheel provided with excavating buckets around its circumference. This excavating wheel is an"open wheel"; that is, it has no axle, but revolves upon anti-friction wheels placed just outside the rims of the excavating wheel.

These buckets have a top and back, but no bottom. They are shaped somewhat like a bowl of a drag-scraper, and as the excavating wheel revolves, each bucket cuts off a slice of earth sufficient to fill it. When the excavating bucket reaches the end of the arc near the top of the wheel, the dirt falls out of the bucket upon a belt conveyor. The wheel is revolved by means of a pair of driving sprockets, which mesh with the segmental gearing.

An advantage claimed is that doing away with the axle relieves the machine of great torsional strains.

The excavating wheel is supported between two beams, which can be raised or lowered. The rear end of the frame is

supported by a post, to the lower end of which a shoe is fastened. This shoe is equipped with a roller to carry the weight.

The excavating buckets of the contractors' type are provided with teeth or rooters, bolted to the heavy steel bucket tops. The side cutters are bolted to the rims of the excavating wheel. They serve to slice off the sides of the trench, while the rooters loosen up the center.

The following illustrations show three different types manufactured by this Company. (Nos. 1, 2, and 3.)

These machines are capable of digging 1200 lineal feet per day of 10 hours in a trench 26 inches wide by 7 feet deep. This is the maximum rate at which it can be operated by an experienced crew. The estimated cost per day is as follows.

	Per Day
1 operator	$5.00
1 fireman	2.50
1 oiler	2.50
1 laborer	1.75
1 blacksmith for 1/2 day .	1.25
1500# of coal at $4 ton...	3.00
Total	$16.00

With 900 lineal feet of trench excavated, the cost is less than 2 cents per lineal foot, or less than 3 1/2 cents per cubic yard, not including depreciation or interest.

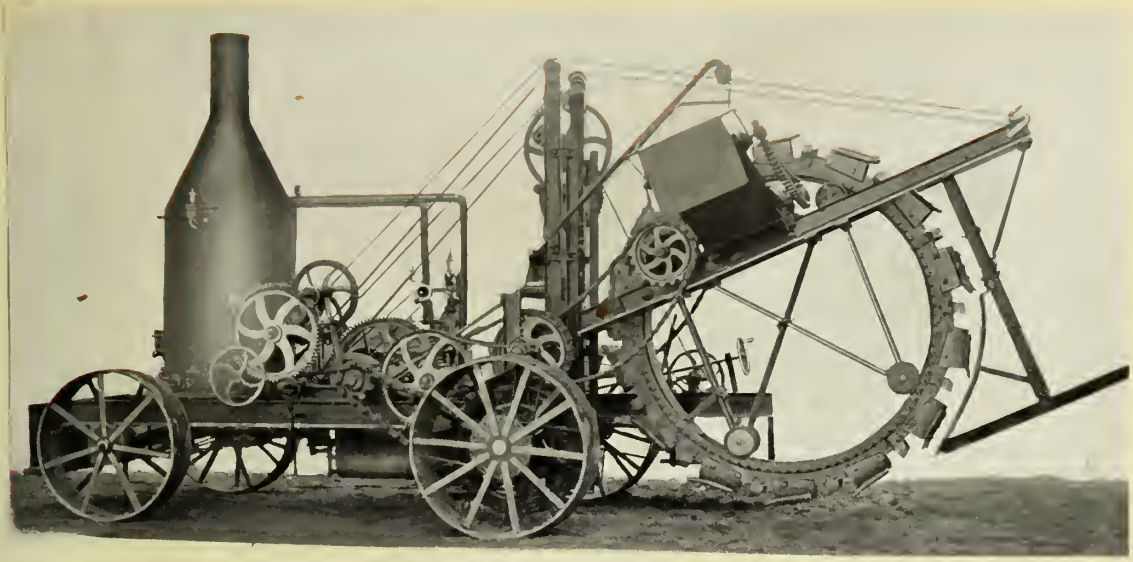


Figure 1.

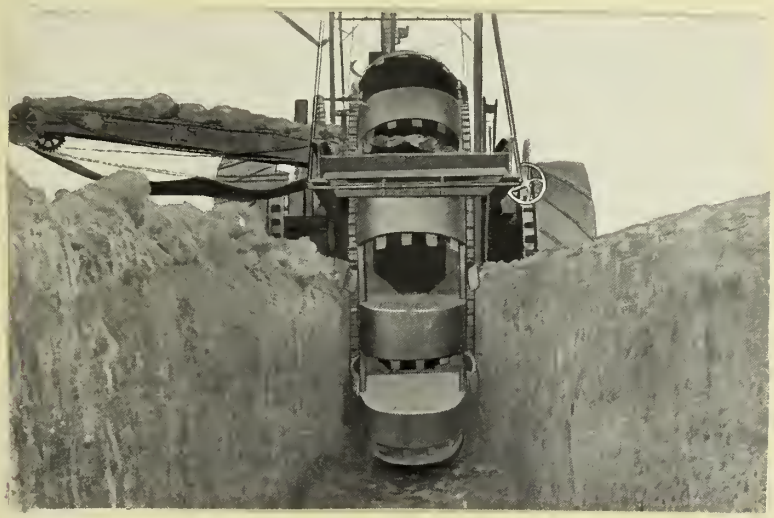


Figure 2.

Figure 3.

AMERICAN MACHINE

The principle of the American Ditcher is very similar to that of the Buckeye. It is, however, more compact with fewer working parts. The digging wheel is driven from an axle. It is 9 ft. 4 in. in diameter. On the spokes is fastened an oval rim 22 inches wide. On the center of this rim and around its complete circumference is riveted a 6 inch I-beam. On the outer flange of this I-beam is bolted another oval rim 22 inches wide. Across the 22 inch outer rim 16 openings 6 inches wide are cut. On one edge of these openings are bolted cutting knives of hard cutter crucible steel.

The power used in this machine is gasoline. The machine is capable of making from 3 to 4 miles an hour when traveling on the road.

Figure No. 1 shows the details of the buckets.

Figure No. 2 shows the machine in operation.

The cost of operation is estimated as follows:

	Per Day
Operator	$4.00
2 ditch men at $2.50	5.00
25 gallons gasoline	3.35
Oil and lubrication	.50
	$12.85

If the machine dug 900 lineal feet, the cost would be about 1 1/2 cents per lineal foot, or 6 1/2 cents per cubic yard, not including depreciation or interest.

Figure 1.

Figure 2

CONCLUSION

The difficulties as well as the efficiency of hand excavation is extremely variable. Jobs are frequently delayed for great periods of time by labor disturbances. The class of workmen obtainable is frequently poor and of varying nationalities, and, owing to the hard and tiresome work, they most generally strike an "easy going" pace which results in low efficiency.

Machinery has to a great extent replaced hand labor. In some instances on large jobs, where they are isolated, the expense of installing machinery would be prohibitive; consequently hand labor is preferable. The advantages gained in using machinery are: less obstruction to traffic; greater speed; a more efficient organization; and frequently greater economy.

When machinery is used, the cost of excavating does not increase as rapidly with the depth as when hand labor is used. In the latter, the material is handled two or more times for varying depths of trenches beyond 8 feet in depth; the cost of this re-handling increases rapidly with each lift.

The force of men necessary to operate trench machines is comparatively small. The crew of a steam trencher is as follows: 1 operator, 1 fireman, 1 oiler, 1 laborer, and 1 blacksmith. With this force of men the daily expense for help averages about $14.50. Where gasoline is used for fuel, the crew is 1 operator, 1 blacksmith, and 2 helpers; and the daily

payroll is about $12.

In some instances, where the earth is very soft or stony, an additional helper is needed to aid the machine in its progress by placing tread planks.

In hand excavation the earth is handled, in deep trenches, oftener, and the walls of the trench frequently are not left in a safe condition. The work progresses more slowly, and is at any time likely to be delayed.

When the machine is used for excavation, the work can be carried on without labor troubles, owing to the small force necessary. The trenches are dug the required depth, and the walls are true.

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